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MULTIPURPOSE WATER HEATER

by
Eric C. Guyer
and
Karl G. Coumou

Yankee Scientific, Inc.
Medfield, MA 02052

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This final report describes SBIR Phase II project for the development of a multi-purpose water heater for use in Army Food sanitation centers. The objective of the project was to develop a water heater -- powered only by an M2 burner and requiring no external supply of electricity--capable of supplying a continuous flow of pressurized hot water to a faucet at the sanitation sink. In the course of the research, two developments took place that have had an impact on the final design. First, the Multifuel Burner Unit (MBU) became available as a potential replacement for the M2. The MBU runs on JP-8 or diesel fuel and requires an external 24-volt VDC power supply. Thus, in anticipation of eventual conversion from M2 to MBU, a DC-Powered Water Heater was also delivered. Second, a new method for heating water in the sanitation sinks was developed allowing three sinks to be heated by a single M2 or MBU.

14. SUBJECT TERMS
MULTIPURPOSE WATER HEATER, M2 BURNER, SANITATION CENTER, PRESSURIZED WATER, CONTINUOUS FLOW, HOT WATER, FOOD SERVICE, FIELD FEEDING, WATER PUMPS, GENERATORS

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Preface

This report describes research undertaken by Yankee Scientific of Medfield, MA under contract No. DAAK60-95-C-2020 during the period from October 1995 to August 1997.

The research focused on the development of a multi-purpose water heater for use in U.S. Army Food Sanitation Centers. The objective of the project was to create a water heater, powered only by an M2 burner and requiring no external supply of electricity, capable of supplying a continuous flow of pressurized hot water to a faucet at the sanitation center sink.

Multi-Purpose Water Heater
Section 1
Introduction

This final report describes the SBIR Phase II project for the development of a multi-purpose water heater for use in Army food sanitation centers. The objective of the project was to develop a water heater - - powered only by an M2 burner and requiring no external supply of electricity - - capable of supplying a continuous flow of pressurized hot water to a faucet at the sanitation center sink (Figures 1a and 1b). Fresh water may be drawn from a supply tank at ground level.

The design specifications call for a water heater capable of delivering up to 1.5 GPM of hot water at a discharge pressure of 25 psi. At a flow rate of 1.5 GPM and with the M2 burner operating at its maximum output of approximately 60,000 Btu/hr, the design objective was to raise the water temperature by 60° F. These specifications have been surpassed by the self-powered water heater developed in this project.

Power for the water pump is supplied by a thermoelectric generator. The heat source for the generator is the M2 burner. Because thermoelectric devices have typical conversion efficiencies of 4% to 5%, most of the heat input must be rejected from the generator. The flow of water that is used to cool the thermoelectric generator is the same as the one subsequently heated in the appliance and delivered to the faucet. Thus, nearly all of the heat input to the generator is used beneficially and the overall efficiency of the self-powered water heater is very high.

In the course of the project, two developments took place that have had an impact on the final design. First, the new Multi-fuel Burner Unit (MBU) became available as a potential replacement for the M2. The MBU runs on JP-8 or diesel fuel. Because this burner requires an

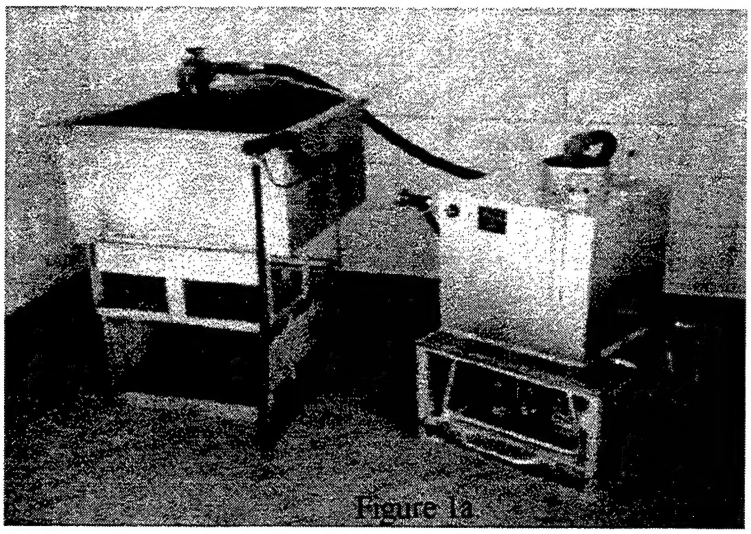

Figure 1a.

Self-Powered Multi-Purpose Water Heater with Sanitation Center Sink

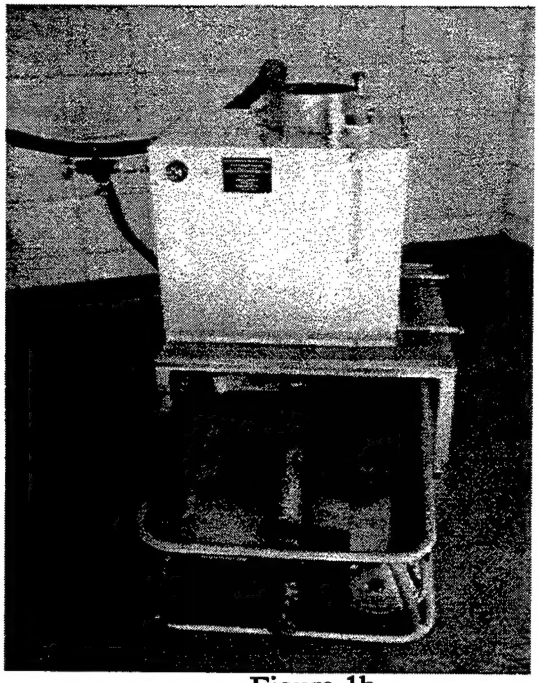

Figure 1b.

Self-Powered Multi-Purpose Water Heater with M2 Burner

external 24 VDC power supply, using the MBU as the heat source for a sanitation center water heater reduces the value of self-powering: the same 24 VDC electrical supply can now also be used to drive the water pump. Thus, in anticipation of eventual conversion from the M2 to the MBU, a DC-Powered Water Heater has also been delivered to the Army as part of this project. This unit is smaller, lighter, and less expensive than the Self-Powered Water Heater.

Second, a unique new method for heating water in the sanitation center sinks was developed allowing three sinks to be heated by a single M2 or MBU. This is done by generating near-atmospheric pressure steam in the water heater and allowing the steam to condense directly in the standing water in the sinks. In less time than it takes to heat the contents of all three sanitation center sinks from below with individual burners, a single steam generator powered by a single burner can achieve the same result with condensing steam.

The design of the self-powered and DC-powered water heaters have been modified to incorporate the steam heating feature. Because of the dual capability of providing pumped hot water as well as steam for heating of a sink filled with water, the final units have been labeled the Self-Powered and DC-Powered Multi-Purpose Water Heaters. Both units are described in detail in this final report.

Section 2
Description

2.1 Self-Powered Multi-Purpose Water Heater

The self-powered water heater is intended for use with the M2 burner and requires no external source of electrical power. The design is based on the indirect heater concept shown in Figure 2. Five inclined aluminum fin tubes are welded to the inside wall of a rectangular shaped reservoir, also made of aluminum, containing approximately 45 lbs. of water. Heat from the M2 combustion gases is transferred through the fin tubes to the water in the reservoir which initially heats up at a rate of about 17 ° F per minute.

At the same time, the combustion gases heat the thermoelectric generator. Within one or two minutes after placing the burner underneath the water heater, the generator output voltage reaches the threshold value for starting the pump motor and water can begin to flow through the copper heating coil submerged in the reservoir. The pumped water is heated as it flows through the coil in the same manner as domestic hot water is heated in a tankless coil that runs inside the hot water boiler of a residential heating system. If the hot water discharge is connected to a faucet on the sanitation center sink, the pump stops automatically when the faucet is closed. Closing off the discharge side of the pump raises the outlet pressure. When the discharge pressure reaches approximately 45 psi, a switch in the pump opens and cuts power to the motor. Opening the faucet lowers the outlet pressure. When the pressure drops below 25 psi, the switch closes again and restores power to the motor. A pressurized expansion tank on the discharge side of the pump takes in approximately 0.5 gallons of water between the pump cut-in and cut-out

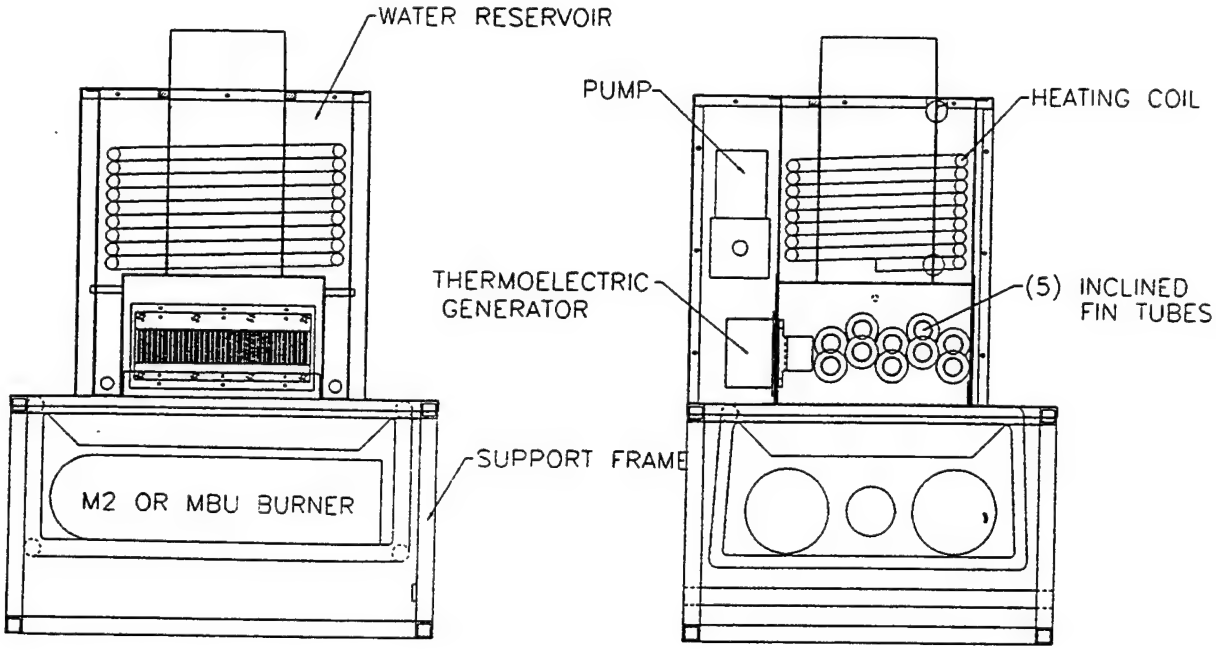

Fig. 2. SELF-POWERED MULTI-PURPOSE WATER HEATER PROVIDING PUMPED HOT WATER AND LOW PRESSURE STEAM

pressure settings. At low flow rates this reduces the number of times the pump cycles off and on.

The steady state water temperature in the reservoir and the outlet temperature of the water flowing through the coil depend on the flow rate and on the efficiency of the water heater. Tests have shown that a maximum flow rate of 2 GPM is attainable when the outlet faucet is full open and that the steady state heat input to the water flowing through the coil is greater than 45,000 Btu/hr. Thus, at the maximum flow rate, the water outlet temperature is 45° F to 50° F higher than the inlet temperature.

The indirect heater design was chosen because it allows the appliance to be used in a practical manner with built-in safeguards against damage or injury and without requiring vigilance on the part of the operating personnel. The M2 burner is manually controlled and has no means of automatic shutdown in case of an impending emergency. Typically, when using hot water at a sink, the flow is not continuous but may be intermittent by periodic opening and closing of the faucet. When the faucet is closed while the burner is still running, the heat energy into the appliance can no longer be removed by the water flowing through the coil and, as a consequence, the water temperature in the reservoir goes up. The 45 lbs. of tank water take about 5 minutes to reach the boiling point. Thereafter it would take 45 minutes to boil off the entire contents of the reservoir before irreparable damage would occur. Without the presence of a water reservoir as a medium to transfer heat from the combustion gases to the water flowing through the coil, the flow could not be stopped for any reason without, at the same time, turning the burner down or off. To do otherwise would almost instantly convert the remaining water inside the coil into high pressure steam with the likelihood of an accident. Clearly, this would not be a practical water heating appliance. With the indirect design, provisions were made to feed makeup water into the reservoir during steam generation thereby further reducing the possibility of damage as a result of operating personnel inattention.

When it is desired to heat sanitation sink water by steam injection, the water flow through the heating coil must first be stopped by turning the faucet off. With the burner running, the reservoir water temperature increases until it reaches the boiling point. Since the reservoir is open to the atmosphere, the maximum water temperature thus becomes 212° F. Steam flowing from the vessel through an opening in the top panel, to which a hose may be attached, can now be used for a variety of applications including the efficient heating of a large volume of water by condensing the steam in the water (sparging). The water inside the heater reservoir that is converted to steam at the rate of about 45 lbs/hr is continuously replenished. A float-actuated valve in the reservoir opens when the water level drops. As the valve opens, water flows from the expansion tank into the reservoir thereby slowly lowering the tank pressure. When the pressure drops below 25 psi, the pump switches on and refills the tank.. As soon as the water pressure reaches 45 psi, the pump automatically switches off again. Thus, as long as there is sufficient cold water available on the inlet side, the heater reservoir is always kept full during steam generation and there is little chance of the reservoir running dry thereby damaging the unit.

2.2 DC-Powered Multi-Purpose Water Heater

This version of the water heater is similar to the self-powered unit except for the absence of a thermoelectric generator to drive the pump. The DC-powered unit is designed for use with the Army's new Multi-fuel Burner Unit (MBU) which operates on 24 VDC supplied in the field by an external power generator. The availability of electrical power allows the pump to be driven by the same power source and eliminates the need for a built-in generator.

Elimination of the thermoelectric generator reduces both the cost and the weight of the water heater. Using the MBU, which requires 24 Volt power, offers an opportunity for adding another safety feature to the water heater which reduces the possibility of damage should the

boiler accidentally run dry while generating steam because the supply of makeup water has run out.

All electrical power to the DC-powered water heater passes through a latching relay inside the unit which can only be closed by manually pressing a push button in an outside panel. An auxiliary power outlet after the relay provides the 24 Volts to the MBU. When the relay opens, power to the water heater and to the MBU is cut. The holding circuit for the relay coil includes a push button switch in the outside panel of the water heater, allowing the unit to be turned off manually, and a thermostat switch activated by a bulb sensor located above the finned boiler tubes. As long as there is water inside the tubes, the combustion gases cool off as they flow past the fins. The sensor temperature is low and the thermostat is set to remain closed. When the tubes run dry, less heat is transferred from the combustion gases which are now much hotter as they flow past the bulb sensor. The thermostat contacts open thereby breaking voltage to the relay coil and all power to the water heater is cut, including to the MBU.

Section 3
Performance Data

The overall efficiency of the water heater when used as an appliance for producing a flow of hot water from a faucet is approximately 80%. As shown in Figure 3, with a 60,000 Btu/hr burner (M2 or MBU) the net water heating capacity is 48,000 Btu/hr. This high efficiency is achieved through the use of finned boiler tubes and a design where the combustion chamber walls and chimney are all in direct contact with the heated water.

When the self-powered water heater is operating at steady state with the burner adjusted for maximum output, the thermoelectric generator output voltage is approximately 8 VDC. At this voltage and with the faucet fully open, the pump produces a flow rate of 2 GPM. Figure 4 shows how the flow rate declines as the discharge pressure is increased by slowly closing the faucet. At 45 psi back pressure, the pump automatically shuts off. The flow rate from the 24 Volt DC-powered water heater is about 25% higher than that shown in Figure 4.

The water temperature increase in the heater can be calculated from the net burner output and the water flow rate. With the burner operating at maximum output, the water temperature rise over a range of flow rates is shown in Figure 5. By adding the water inlet temperature to the increase, the discharge temperature can be computed for various flow rates.

Figure 6 shows the faucet outlet temperature for a supply water temperature of 60° F. With the faucet fully open, water is continuously available at about 110° F. By partially closing the faucet, a slower flow of hotter water is available, up to 160° F. The water temperature inside the heater reservoir also depends in the flow rate. During typical intermittent hot water use, the reservoir temperature levels off around 180° F to 190° F. If the flow remains shut off with the heater running, the reservoir water quickly heats up to 212° F and begins to boil. The water

SELF-POWERED AND DC-POWERED MULTI-PURPOSE WATER HEATER

(used to produce pumped hot water)

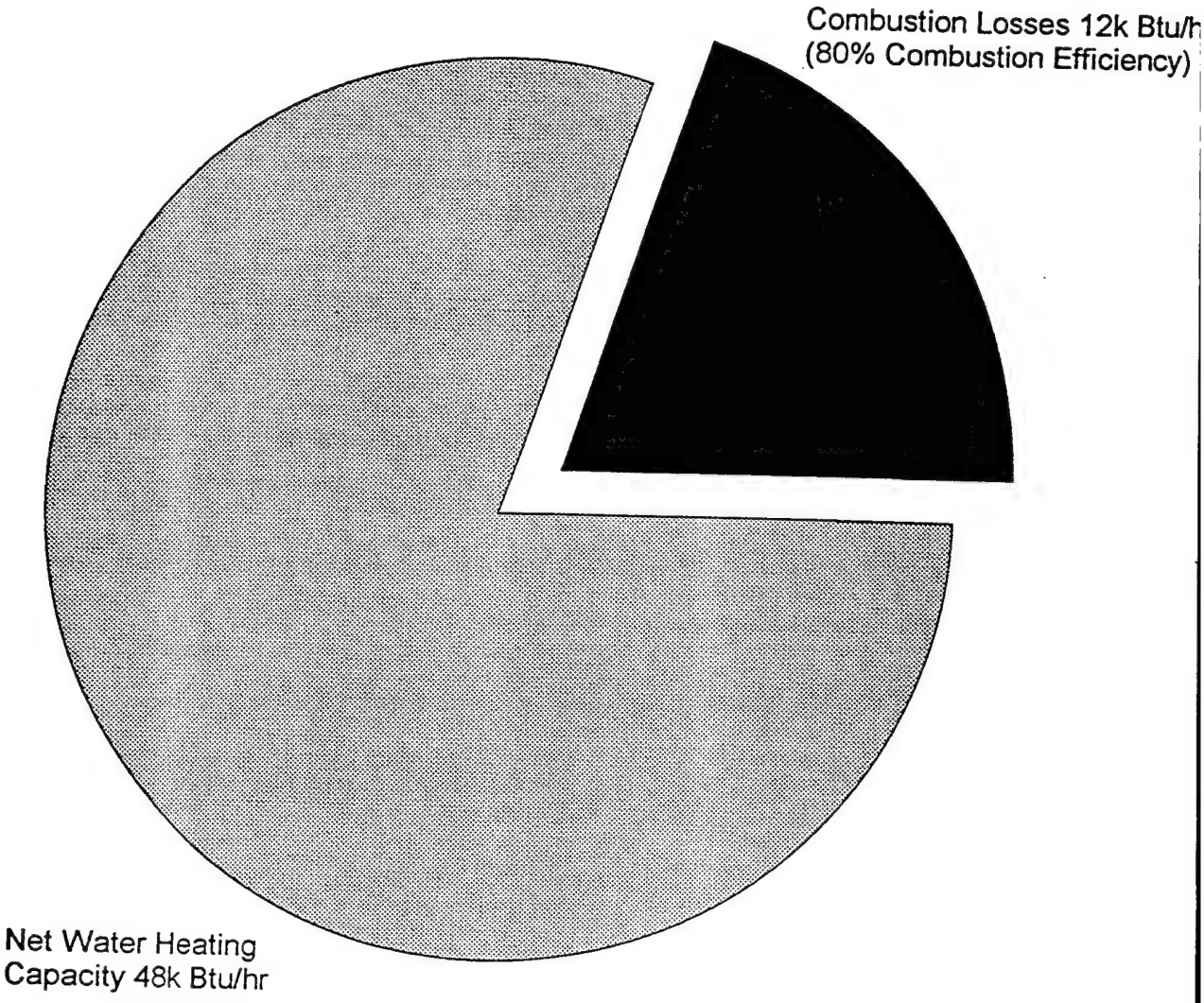

Fig. 3. Heat Allocation using 60k Btu/hr burner

SELF-POWERED MULTI-PURPOSE WATER HEATER

(DC-powered water heater has approximately 25% higher flow rate)

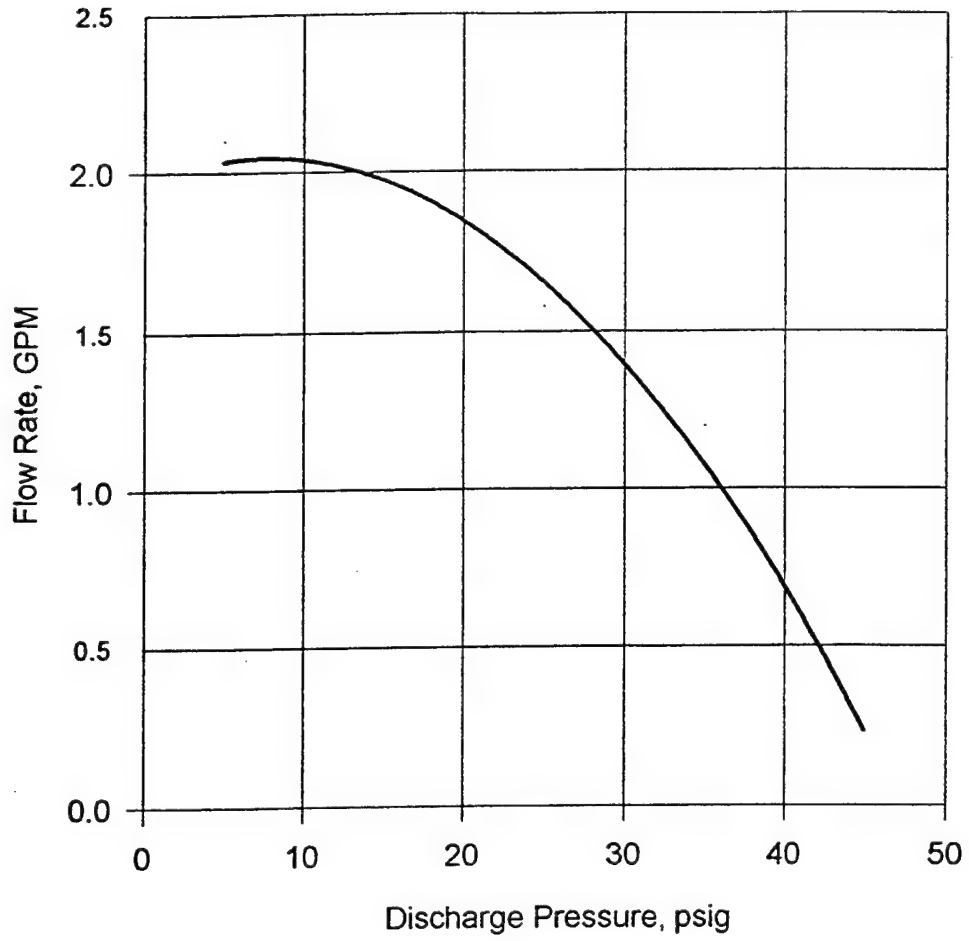

Fig. 4. Hot Water Flow Rate vs. Discharge pressure

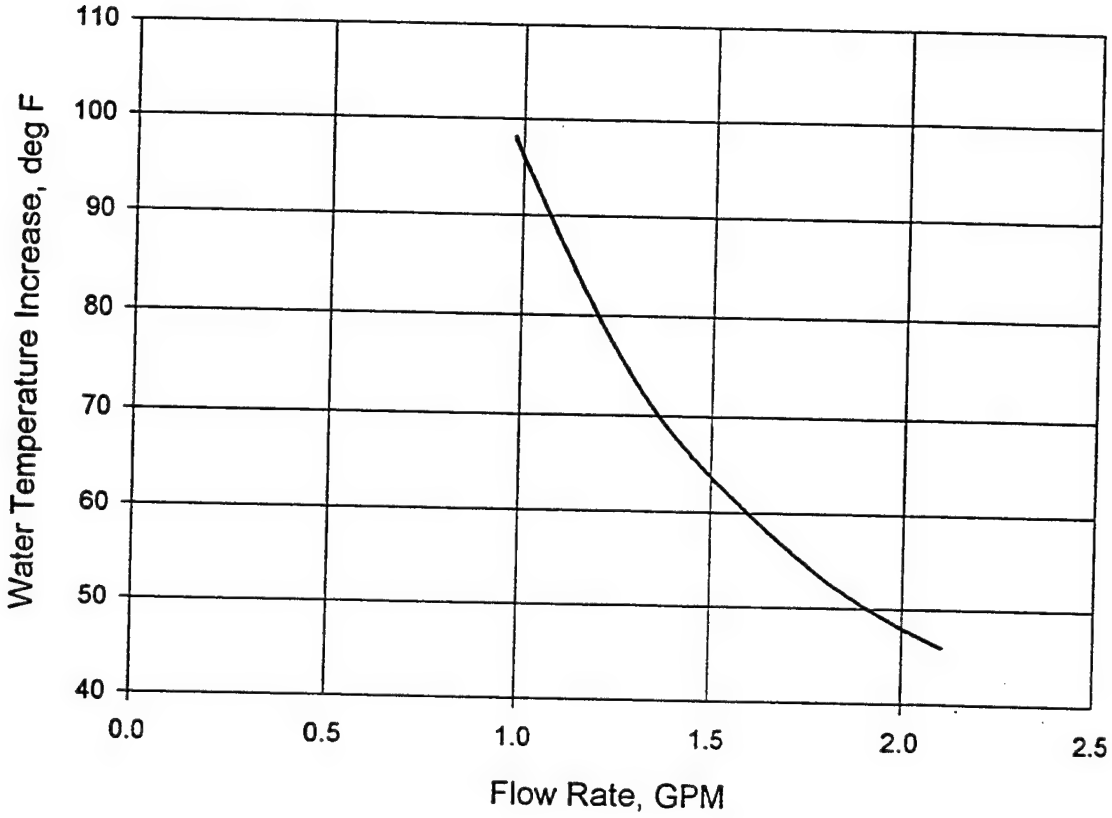

Fig. 5. Water Temperature Rise vs. Flow Rate

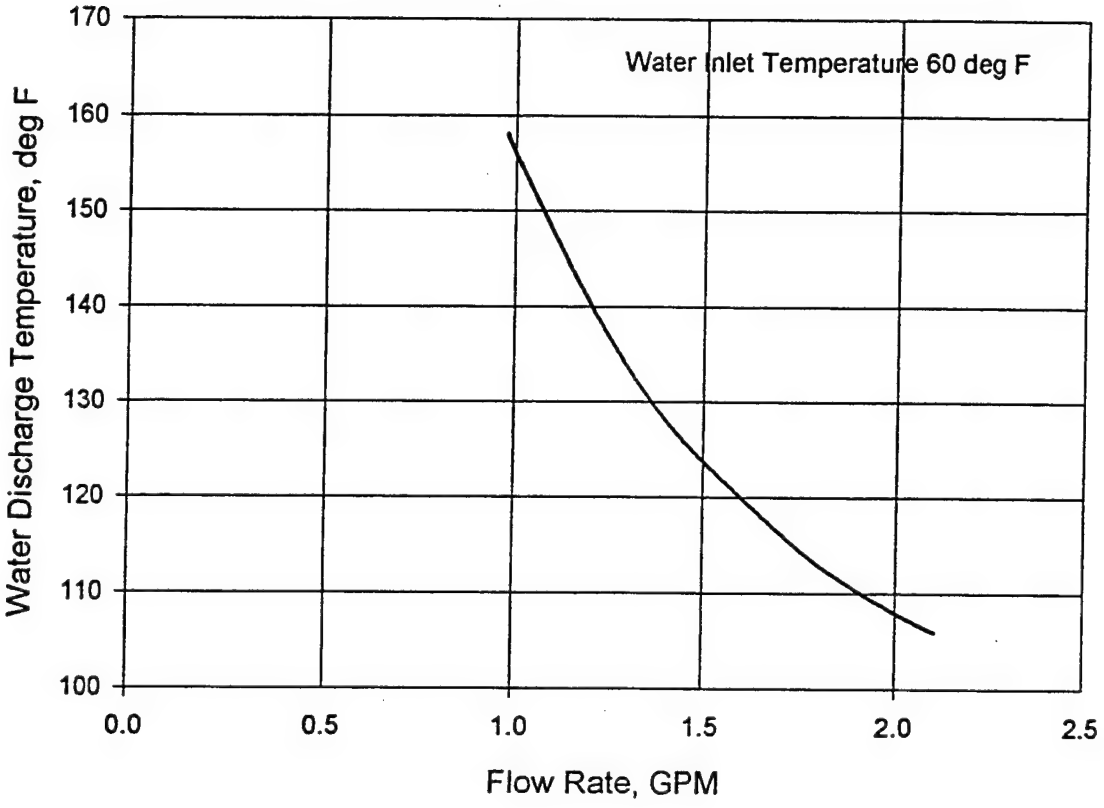

Fig. 6. Water Discharge Temperature vs. Flow Rate

residing inside the coil also reaches 212° F but cannot boil because it is in a confined space. When the faucet is opened and water is being pumped again through the appliance, the first water exiting from the coil is at 212° F. To reduce the possibility of scalding water flowing from the faucet, a mixing valve, similar to that found on residential hot water systems, has been added to the heater. When the exit flow from the coil is above the setpoint of the valve, cold water is mixed in with the hot. This condition exists for only a brief moment until the water outlet temperature from the coil is again in balance with the flow rate and burner output.

Figures 7 and 8 show the performance when the water heater is operated for the purpose of generating steam and the steam is used to heat a volume of water in a sanitation center sink. The net efficiency with which a 20 gallon volume of water in the sink can be heated by a single 60,000 Btu/hr burner is 65% as shown in Figure 7. There are heat losses besides combustion losses that reduce the overall efficiency. First, approximately 5,000 Btu/hr are used to heat the cold makeup water to the boiling point. Makeup water is automatically pumped into the reservoir as the water level drops during steam generation. Then, as the sink water heats up by the injection and condensation of steam, some heat is lost due to evaporation at the free water surface and conduction to the ambient through the metal walls of the sink. The rate at which a 20 gallon volume of water in a sink can be heated from an initial temperature of 60° F is shown in Figure 8.

The temperature of the thermoelectric generator during various modes of operation, ranging from steady water flow through the coil to zero water flow with steady steam generation, has been investigated carefully. There is no automatic control to prevent the thermoelectric modules from overheating. The thermal design of the water heater has been optimized to limit the module temperatures to around 550° F during steady operation under the most severe conditions, namely when there is no flow of cooling water through the generator and the burner is operating at full

SELF-POWERED AND DC-POWERED
MULTI-PURPOSE WATER HEATER

(used as indirect fired water heater
for sanitation sink)

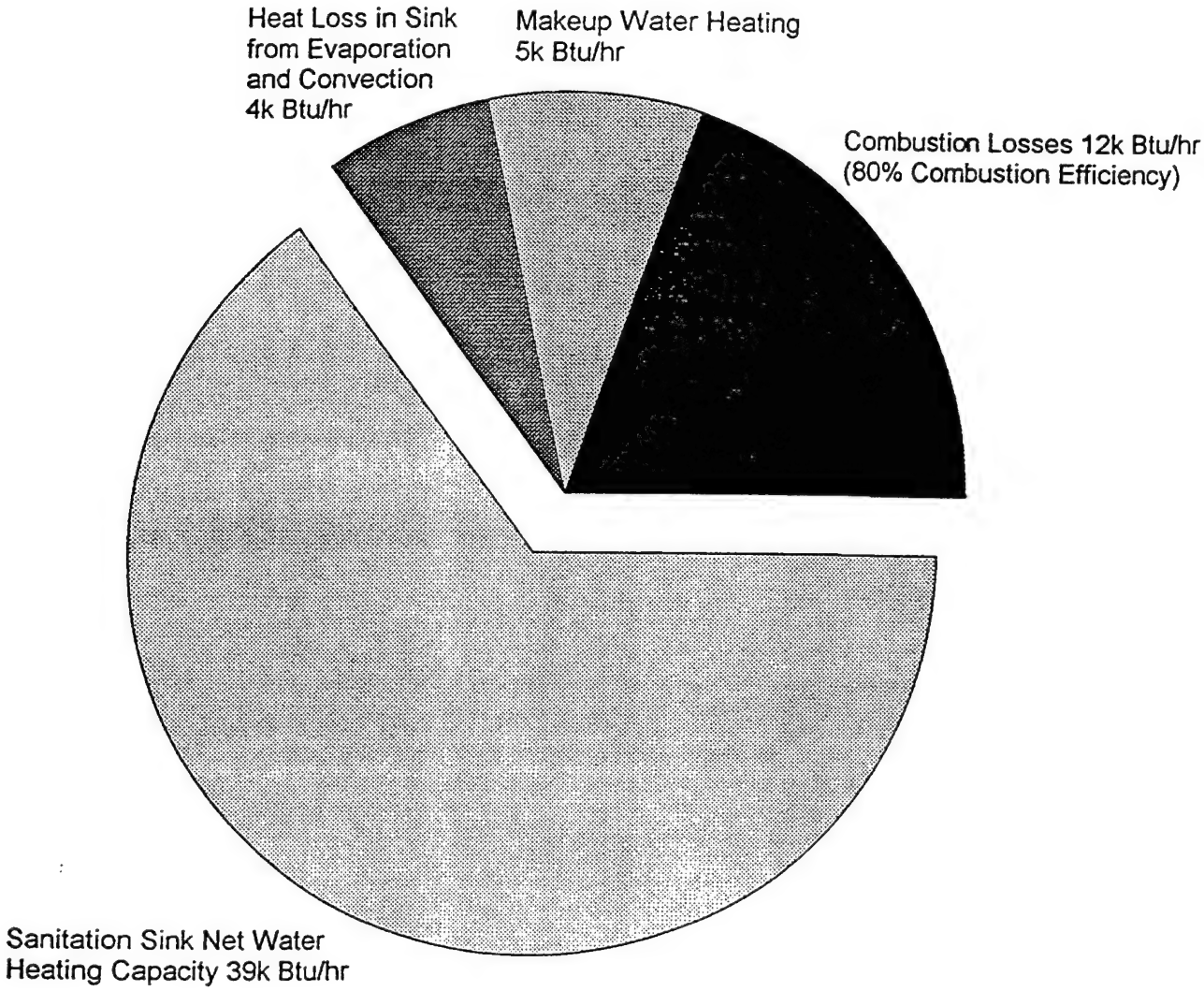

Fig. 7. Heat Allocation using 60k Btu/hr burner

SELF-POWERED AND DC-POWERED MULTI-PURPOSE WATER HEATER

(used as indirect fired water heater for sanitation sink)

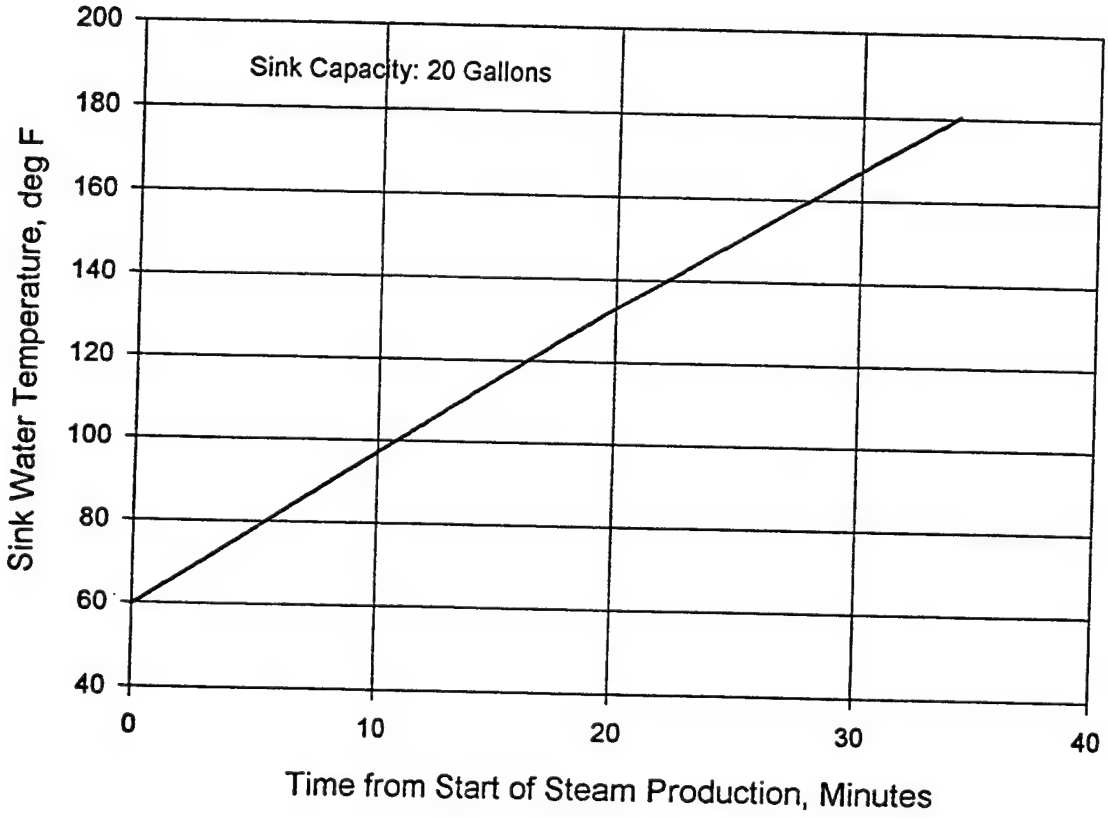

Fig. 8. Sanitation Sink Temperature Rise using Steam Heating

output. This condition may occur when the cold water supply accidentally runs dry (or is obstructed) while the unit is generating steam at maximum capacity. It would take nearly 45 minutes before the water level in the reservoir has dropped to the point where irreversible damage occurs to the boiler tubes. During this time period, the generator must be protected from damage even though there is no normal flow of cooling water. To accomplish this, a second, passive, cooling channel is provided in the generator that is connected at both ends to the water reservoir. During normal operation, when the generator is cooled by cold supply water, this channel is filled with a stagnant amount of reservoir water. When the normal water cooling fails, the generator cold side heats up to 212° F and the water in the auxiliary cooling channel starts to boil. Hot water from the reservoir keeps returning to the cooling channel where it is continuously boiled off. The generator cold side thus remains fixed at 212° F and this, in turn, limits the generator hot side to 550° F. These temperatures have been established as safe for long term exposure of the modules.

Section 4
Technical Details

4.1 Self-Powered Water Heater

The aluminum boiler is fabricated with 0.080" thick sheet metal. Five finned boiler tubes are welded at a 6° angle in the combustion chamber. The tubes are 1" I.D. with a wall thickness of 0.070". The integral fins are 0.380" high by 0.015" thick and are spaced 0.080"apart. Details of the boiler are shown in Figure 9.

The heating coil is located in the reservoir above the combustion chamber (see Figure 2). It consists of a 28 feet length of 1/2" I.D. integral finned copper tubing manufactured by Wolverine shaped into a coil of approximately 9 turns.

The boiler is attached to a mild steel base plate which fits on top of the burner support frame. Including this frame, the overall dimensions of the water heater are 22" wide by 25.5" deep by 36" high. The frame allows placing a burning M2 underneath the water heater and then raising the M2 until its top edge touches the bottom of the base plate. For efficient operation it is critical that the top edge of the burning makes contact with the base plate thereby reducing the amount of excess air drawn into the combustion chamber.

The total weight of the self-powered water heater is 80 lbs. (empty) including the bumer support frame.

4.1.1 Thermoelectric Generator

Power is produced by three HZ-20 thermoelectric modules from Hi-Z Technology connected in series. Figure 10 shows mechanical details of the generator. The modules are held under a high compressive load between a hot and a cold plate. The hot plate includes an array of copper fins

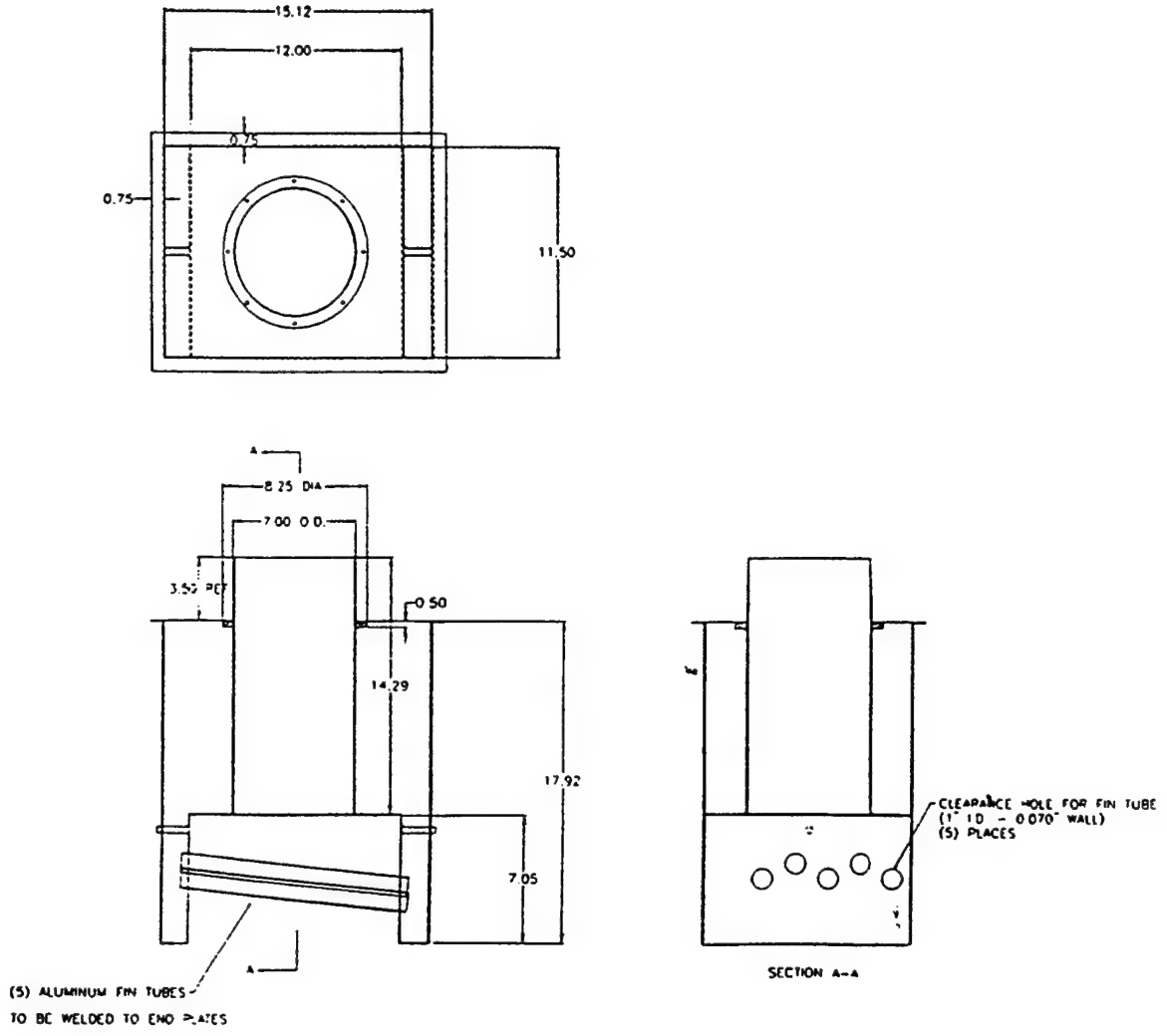

Fig. 9. DETAIL ALUMINUM BOILER

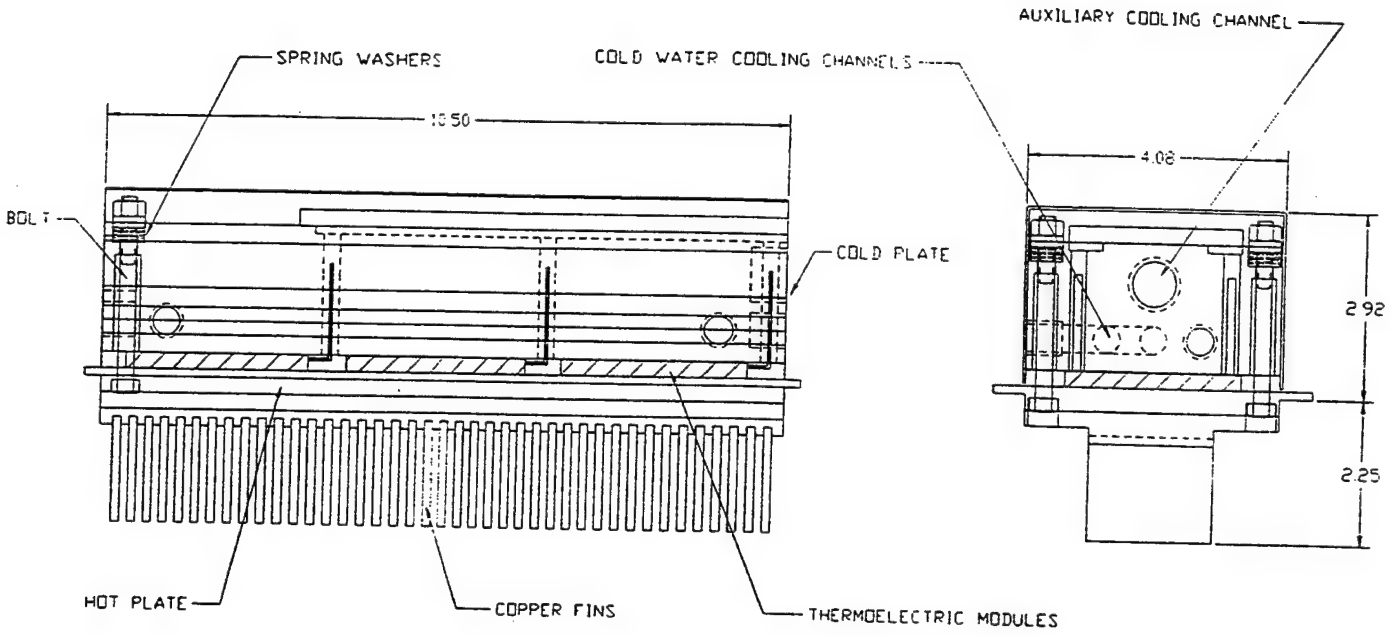

Fig. 10. THERMOELECTRIC GENERATOR

heated by the M2 burner (see Figure 2). To reject heat on the cold side, cooling water can pass through a series of channels in the cold plate. The compressive load is obtained by tightening eight bolts, each with a set of Belleville spring washers. An additional cooling channel in the cold plate is for emergency use when the flow of makeup water that would normally pass through the cold water cooling channels is accidentally interrupted (see Section 3 for further details). The generator weighs approximately 25 lbs. including fittings.

The voltage output from a thermoelectric generator depends on the temperatures on both sides of the modules and on the load requirements. In the water heater, the normal cold side temperature with intake water from a supply tank at ambient temperature is around 100°F. Under these conditions, and with the burner operating at maximum output, the hot side temperature will stabilize around 425° F. The corresponding open circuit voltage at the generator is then 12 VDC.

Because of the output characteristics of thermoelectric modules, when the generator is connected to the water pump - a Flojet Model 4300-142 designed for nominal 12 VDC operation - the generator output voltage drops below 12 Volt. The steady operating voltage is reached when the required pump power matches the available generator power. With the faucet full open and the pump outlet pressure at a minimum, the generator voltage is approximately 8 VDC.

4.1.2 Water Heater Schematic

As shown in Figure 11, the circulating pump motor is connected directly to the thermoelectric generator. The three thermoelectric modules are connected in series.

When the water heater is used to produce steam, the circulating pump provides makeup water to the reservoir in response to the opening and closing of the float valve. Because the pump flow rate is many times greater than the rate at which boiler water is used up, a pressurized expansion tank with a capacity of 0.5 gallons has been added to the system to reduce the number of pump on-off cycles.

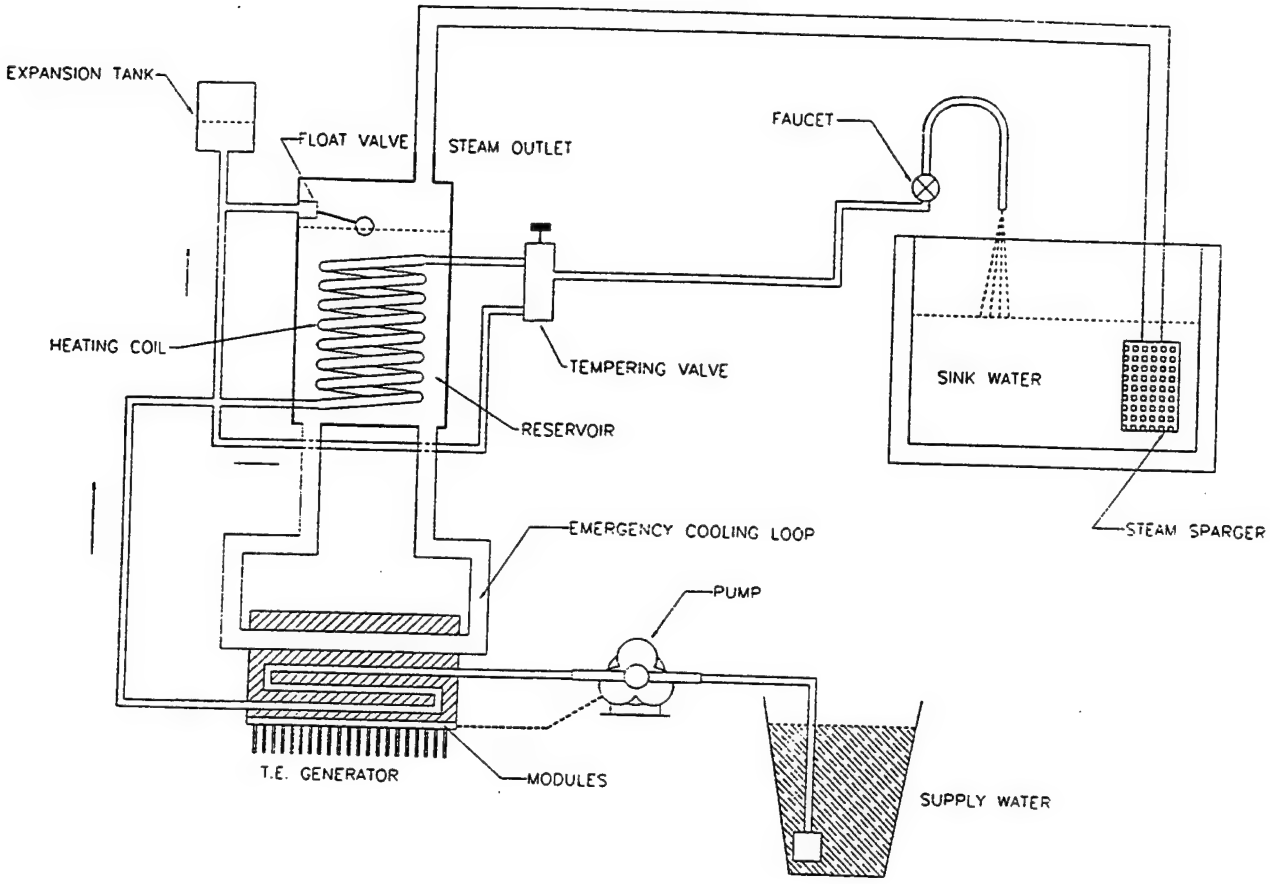

Fig. 11. SCHEMATIC OF SELF-POWERED MULTI-PURPOSE WATER HEATER

4.2 DC-Powered Water Heater

The boiler of the DC-powered water heater is constructed similar to the self-powered unit. As delivered to the Army, the DC-powered water heater is mounted on top of a frame for holding the burner. While this frame is required when using the M2 burner, which by Army regulations must be started at a different location and then placed underneath the water heater, the base plate of the DC-powered unit could alternatively be placed directly on top of the MBU. This is because the MBU may be started in place allowing the heater reservoir to be filled with water while the unit is resting on the MBU. Eliminating the burner support frame would reduce the overall height of the assembled water heater by 14", the height of the frame itself. Also, the mild steel base plate could now be reduced in size from 22" by 25.5" to 18.5" by 23.5". Both the cost and the weight of the frame (15 lbs.) could thus be saved.

The absence of a thermoelectric generator from the DC-powered water heater reduces the overall weight by 25 lbs. Thus, during transportation the water heater can weigh as little as 40 lbs. without the frame or 55 lbs. including a burner support frame.

4.2.1 Plumbing Schematic

The plumbing schematic for the DC-powered water heater, shown in Figure 12, is identical to that of the self-powered heater.

4.2.2 Electrical Schematic

Figure 13 shows the electrical details of the DC-powered water heater. Two momentary action push button switches, "ON' and "OFF", are located in one of the outside panels. The "ON"

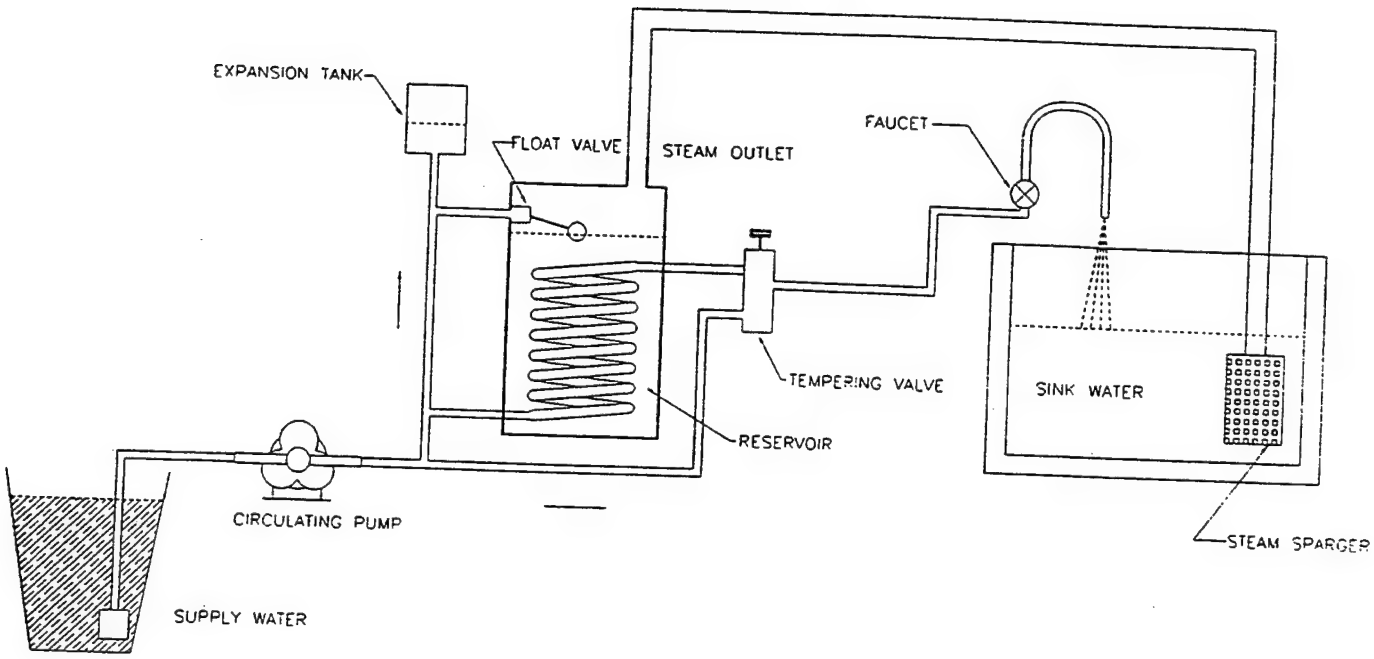

Fig. 12. PLUMBING SCHEMATIC OF DC–POWERED MULTI–PURPOSE WATER HEATER

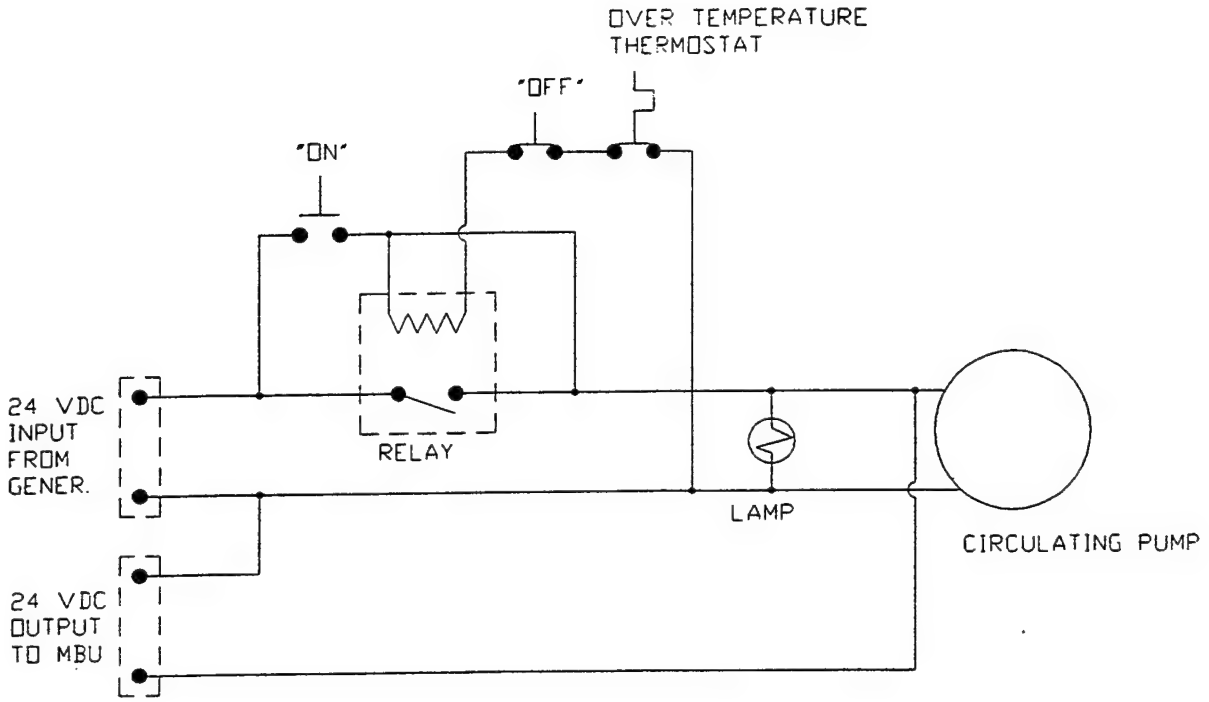

Fig. 13. ELECTRICAL SCHEMATIC OF DC-POWERED MULTI-PURPOSE WATER HEATER

switch is normally open while the "OFF' switch is normally closed. A lamp in the panel indicates that the relay is closed and that the water heater has power.

The over-temperature thermostat is normally closed. The bulb sensor is located above the finned boiler tubes. When the sensor temperature exceeds the set point, the thermostat contacts open thereby breaking the voltage to the relay coil. Power to the circulating pump and, more important, to the auxiliary power outlet for the MBU is cut and remains off until the "ON' button is pressed.

Section 5
Operating Instructions

5.1 Self-Powered Water Heater

5. 1.1 Summary Description

The water heater consists of a boiler containing approximately 6 gallons of water. The water in the boiler is heated by an M2 burner placed underneath. Cold water is pumped through a coil submerged in the boiler and is heated by the boiler water as it flows through the coil.

The water pump is a demand pump meaning that, when the outlet from the coil is closed, the pump automatically turns itself off. Power to run the pump is provided by a built-in thermoelectric generator that is also heated by the M2 burner. After the burner has been placed under the water heater it takes about three minutes until the generator output is high enough to drive the pump.

When there is no flow through the coil, the water temperature in the boiler continues to rise until, eventually, it reaches the boiling point (212° F) and steam is being generated in the reservoir. From an outlet at the top of the boiler, the steam flow can be connected through a flexible hose to a sparger (steam injector) submerged in a body of water (e.g. a sanitation center sink) that is to be heated. As the steam condenses in the sink it heats the water by giving off the latent heat.

When the unit is operated in the "steam mode", the water level in the boiler drops as water is converted to steam. The reservoir is automatically replenished by the pump through a float

valve that senses the water level in the boiler. If the external supply of cold water runs out and no additional makeup water is pumped into the reservoir, the boiler level will drop in approximately 45 minutes to a point where the boiler tubes run dry and the water heater will be seriously damaged. There is no *automatic switch-off mechanism for the M2 burner in the event that the boiler runs dry.* The water level in the boiler is indicated on a sight glass mounted on the side of the unit. **During all modes of operation, the water level must always be near the Fill Level mark on the sight glass.**

5.1.2 Connections

1. Clamp washdown assembly (faucet and spray head) to the rear edge of the Sanitation Center sink, in the middle.

2. Clamp steam injector/valve assembly to the rear edge of the Sanitation Center sink, to the left of the washdown assembly as seen from the front.

3. Attach 1-1/4" I.D. rubber hose between steam outlet at top of boiler and steam injector/valve assembly inlet at sink.

4. Connect 1/2" I.D. water hose to Hot Water Discharge at the boiler and to the faucet inlet at the sink.

5. Connect suction hose to Water Intake at the boiler. Place screen basket in a cold water supply tank or barrel, making sure that basket remains at the bottom.

5.1.3 Operating Procedure

1. Fill boiler with fresh water through the fill opening at the top. Fill to the Fill Level mark indicated on the sight glass. Close fill opening.

2. Place the brass deadweight on the 1/2" hole at the top of the steam outlet.

3. Lower the front of the burner support tray beneath the unit.

4. Following Army regulations, start the M2 burner.

5. Place the M2 burner on the support tray and push it all the way to the back. Lift the front of the tray and lock it in place.

6. Adjust the M2 burner to its maximum capacity.

7. After approximately 3 minutes the unit is ready to start pumping water to the faucet.

WARNING: THE WATER HEATER SHOULD NOT BE LEFT UNATTENDED WHILE IN OPERATION!

The water outlet temperature at the faucet or spray head depends on the flow rate and on the water inlet (supply) temperature. During steady water delivery with the faucet turned full open, the water discharge temperature is approximately 50° F higher than the supply temperature. By turning the faucet to a lower flow rate, the discharge temperature increases proportionately.

When using the spray, first turn the faucet off. This increases the flow to the spray head.

5.1.4 Important notes

1. The water heater is provided with a tempering valve. This mixes cold supply water with hot water from the heating coil before it reaches the faucet and thus prevents the discharge of excessively hot water. The temperature valve is NOT a water temperature control valve; it only *limits* the maximum water discharge temperature. The tempering valve can be adjusted for different outlet temperatures between 120° F and 160° F. Because of the uncertainty of the inlet (supply) water temperature to this water heater, the tempering valve cannot in all situations prevent scalding hot water from reaching the faucet. The user must therefore always be careful when first opening the faucet or spray head. If the discharged water appears too hot, the recommended procedure is to turn the faucet full open and wait for a few minutes for the water temperature to drop (assuming that the supply water is cold).

2. If the faucet and spray head remain turned off for more than about five minutes, water in the boiler will reach 212° F and begin to boil. Steam will exit from the top opening. This is normal. Unless the intent is to generate steam for heating purposes (see below), the M2 should be turned to a lower firing rate until the boiling stops or is reduced to a minimum amount of steam generation.

3. If the water heater is to be used in the "steam mode" of operation, first check to make sure that the screen basket of the water intake hose is submerged in a bucket or supply tank filled with at least 10 gallons of water. The Sanitation Center sink must be filled with about 20 gallons of cold water. With the faucet and spray head turned off and the steam outlet at the boiler connected by hose to the injector valve at the sink, steam will be generated in the boiler after several minutes and this steam will condense in the sink water thereby heating the water at a rapid rate. When the desired sink temperature has been reached, close the injector valve. Steam will now exit from the relief valve at the boiler. Turn the M2 burner down until the boiling stops or the rate of steam generation is reduced to a low level.

4. The steam relief valve at the boiler opens whenever the inside pressure exceeds 1 psi. If, for any reason, the relief valve fails to open, a deadweight relief on the steam outlet will be blown off its 1/2" dia. opening when the pressure exceeds 2 psi. **Do not tamper with either of these safety features or serious personal injury may result.**

5. The boiler does not need to be drained after each use. In fact, it is advantageous to use the same water inventory in the boiler as fewer minerals will be deposited in the boiler tubes.

5.2 DC-Powered Water Heater

5.2.1 Summary Description

The water heater consists of a boiler containing approximately 6 gallons of water. The water in the boiler is heated by an MBU burner placed underneath. Cold water is pumped through a coil submerged in the boiler and is heated by the boiler water as it flows through the coil.

The water pump is a demand pump meaning that, when the outlet from the coil is closed, the pump automatically turns itself off. The pump requires 24 VDC power provided by an external supply. The MBU is powered from a 24 VDC auxiliary outlet on the water heater.

When there is no flow through the coil, the water temperature in the boiler continues to rise until, eventually, it reaches the boiling point (212° F) and steam is being generated in the reservoir. From an outlet at the top of the boiler, the steam flow can be connected through a flexible hose to a sparger (steam injector) submerged in a body of water (e.g. a kitchen sink) that is to be heated. As the steam condenses in the sink it heats the water by giving off the latent heat.

When the unit is operated in the "steam mode", the water level in the boiler drops as water is converted to steam. The reservoir is automatically replenished through a float valve that senses the water level in the boiler. If the external supply of cold water runs out and no additional makeup water is pumped into the reservoir, the boiler level will drop in approximately 45 minutes to a point where the boiler tubes run dry. An over-temperature sensor is attached to the outside of the boiler tubes opposite the burner. The thermostat is set to interrupt power to the MBU as soon as the sensor temperature increases as a result of reduced heat transfer between the combustion gas and boiler tubes.

The water level in the boiler is indicated on a sight glass mounted on the side of the unit. **During all modes of operation, the water level must always be near the Fill Level mark on the sight glass.**

5.2.2 Connections

6. Clamp washdown assembly (faucet and spray head) to the rear edge of the Sanitation Center sink, in the middle.

7. Clamp steam injector/valve assembly to the rear edge of the Sanitation Center sink, to the left of the washdown assembly as seen from the front.

8. Attach 1-1/4" I.D. rubber hose between steam outlet at top of boiler and steam injector/valve assembly inlet at sink.

9. Connect 1/2" I.D. water hose to Hot Water Discharge at the boiler and to the faucet inlet at the sink.

10. Connect suction hose to Water Intake at the boiler. Place screen basket in a cold water supply tank or barrel, making sure that basket remains at the bottom.

11. Connect external 24 VDC power source to the input socket marked Generator.

12. Place MBU burner on the support tray below the water heater and push it all the way to the back. Lift the front of the tray and lock it in place. Connect MBU to the auxiliary power outlet on the water heater marked Burner using the power cord provided. (Note: Connecting the MBU directly to a 24 VDC power source instead of using the Burner outlet on the water heater defeats the safety power cutoff in the event that the water heater accidentally runs dry).

5.2.3 Operating Procedure

1. Fill boiler with fresh water through the fill opening at the top. Fill to the Fill Level mark indicated on the sight glass. Close fill opening.

2. Place the brass deadweight on the 1/2" hole at the top of the steam outlet.

3. Press the ON push button. The Power pilot light goes on. If the sink faucet is open, the pump starts automatically and after a few seconds water flows from the faucet. Closing the faucet generally stops the pump. However, if the float valve in the reservoir is still open, the pump will continue to run until the reservoir is completely filled and the float valve closed. (Note: The demand pump is stopped by closing the faucet which raises the outlet pressure at the pump. As the current through the pump motor increases with the outlet

pressure, the supply voltage to the water heater may, depending on the capacity of the DC power supply, momentarily drop below the 24 Volt level. If this happens, the latching relay in the water heater opens and the Power pilot light goes off indicating that the unit has lost power. *This water heater cannot operate correctly on a power supply of inadequate or marginal capacity).*

4. Following Army regulations, start the MBU.

5. Adjust the MBU to its maximum capacity.

6. Pumped water is available at any time by opening the faucet. Initially, cold water flows from the faucet but, as the water in the reservoir heats up, the discharge water becomes hotter until it reaches a maximum temperature which depends on the flow rate as determined by the faucet opening.

WARNING: THE WATER HEATER SHOULD NOT BE LEFT UNATTENDED WHILE IN OPERATION!

The water outlet temperature at the faucet or spray head depends on the flow rate as well as the water inlet (supply) temperature. During steady water delivery with the faucet turned full open, the water discharge temperature is approximately 50 ° F higher than the supply temperature. By turning the faucet to a lower flow rate, the discharge temperature increases proportionately. When using the spray, first turn the faucet off. This increases the flow to the spray head.

7. To turn the water heater and MBU off at any time, press the OFF push button on the water heater. The Power pilot light goes off.

5.2.4 Important Notes

1. The water heater is provided with a tempering valve. This mixes cold supply water with hot water from the heating coil before it reaches the faucet and thus prevents the discharge of excessively hot water. The tempering valve is NOT a water temperature control valve; it only *limits* the maximum water discharge temperature. The tempering valve can be adjusted for different outlet temperatures between 120° F and 160° F. Because of the uncertainty of the inlet (supply) water temperature to this water heater, the tempering valve cannot in all situations prevent scalding hot water from reaching the faucet. The user must therefore always be careful when first opening the faucet or spray head. If the discharged water appears too hot, the recommended procedure is to turn the faucet full open and wait for a few minutes for the water temperature to drop (assuming that the supply water is cold).

2. If the faucet and spray head remain turned off for more than about five minutes, water in the boiler will reach 212° F and begin to boil. Steam will exit from the top opening. This is normal. Unless the intent is to generate steam for heating purposes (see below), the MBU should be turned to a lower firing rate until the boiling stops or is reduced to a minimum amount of steam generation.

3. If the water heater is to be used in the "steam mode" of operation, first check to make sure that the screen basket of the water intake hose is submerged in a bucket or supply tank filled with at least 10 gallons of water. The Sanitation Center sink must be filled with about 20 gallons of cold water. With the faucet and spray head turned off and the steam outlet at the boiler connected by hose to the injector valve at the sink, steam will be generated in the boiler after several minutes and this steam will condense in the sink water thereby heating the water at a rapid rate. When the desired sink temperature has been reached, close the

injector valve. Steam will now exit from the relief valve at the boiler. Turn the MBU down until the boiling stops or the rate of steam generation is reduced to a low level.

4. The steam relief valve at the boiler opens whenever the inside pressure exceeds 1 psi. If, for any reason, the relief valve falls to open, a deadweight relief on the steam outlet will be blown off its 1/2" dia. opening when the pressure exceeds 2 psi. **Do not tamper with either of these safety features or serious personal injury may result.**

5. The boiler does not need to be drained after each use. In fact, it is advantageous to use the same water inventory in the boiler as fewer minerals will be deposited in the boiler tubes.

6. The set point of the over-temperature thermostat can be adjusted over the range 140° F to 600° F by turning the shaft counterclockwise. The shaft is accessible behind the louvered panel. If the power goes off unexpectedly while the water level in the boiler appears to be normal, the thermostat set point may be too low. Turn the shaft counterclockwise by a small amount. The optimum setting as where, during normal operation, the thermostat remains in the normally closed position while a 50 degree Fahrenheit increase in the sensor temperature would open the thermostat.

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Section 6
List of Parts

Below is a listing of Original Equipment Manufacturer's (OEM) components used in the construction of the Water Heaters.

6.1 Self-Powered Water Heater

- Thermoelectric Modules - Model HZ-20 from M-Z Technology, 7606 Miramar Road, San Diego, CA 92126 - (3) required.

- Belleville Spring Washers - Part No. 9713K63 from McMaster-Carr Supply Co., New Brunswick, N. J. 08903 - (72) required.

- Circulating Pump - Model 4300-142 from Flojet Corporation, 12 Morgan Drive, Irvine, CA 92718 - (1) required.

- Mixing Valve - Model 70A-T from Watts Industries, 815 Chestnut Street, N. Andover, MA 01845 - (1) required.

- Float Valve - Part No. 4607K41 from McMaster-Carr Supply Co., New Brunswick, N.J. 08903 - (1) required.

- Liquid Level Gauge - Part No. 1106K3 from McMaster-Carr Supply Co., New Brunswick, N. J. 08903 - (1) required.

- Heating Coil - 28 ft long integral finned copper tubing, Catalog No. 66-114028-01 from Wolverine Tube, Inc., fabricated by Therma-flow, Inc., 191 Arlington Street, Watertown, MA 02172 - (1) required.

6.2 DC-Powered Water Heater

- Circulating Pump - Model 4300-342 from Flojet Corporation, 12 Morgan Drive, Irvine, CA 92718 – (1) required.
- Relay – Model PAM-1 SPDT relay module 24-115V from Kele & Associates, 2975 Brother Blvd., Barlett, TN 38133 – (1) required.
- Over Temperature Thermostat – Model T85A Oven Thermostat from ITT General Controls, 28150 Industry Drive, Valencia, CA 91355 – (1) required.
- Mixing Valve – Model 70A-T from Watts Industries, 815 Chestnut street, N. Andover, MA 01845 – (1) required.
- Float Valve – Part No. 4607K41 from McMaster-Carr Supply Co., New Brunswick, N. J. 08903 – (1) required.
- Liquid Level Gauge – Part No. 1106K3 from McMaster-Carr Supply Co., New Brunswick, N. J. 08903 – (1) required.
- Heating Coil – 28 ft long integral finned copper tubing, Catalog No. 66-114028-01 from

Wolverine Tube, Inc., fabricated by Therma-flow, Inc., 191 Arlington Street, Watertown, MA 02172 – (1) required.